DOCUMENT RESUME

ED 334 976 IR 015 139

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TITLE Harnessing the Power of Interactivity for Instruction.
PUB DATE 91
NOTE 16p.; In: Proceedings of Selected Research Presentations at the Annual Convention of the Association for Educational Communications and Technology; see IR 015 132.
PUB TYPE Viewpoints (Opinion/Position Papers, Essays, etc.) (120) -- Information Analyses (070) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Communication (Thought Transfer); *Computer Assisted Instruction; Computer Simulation; Courseware; Feedback; *Instructional Design; *Interaction; Learner Controlled Instruction; *Man Machine Systems; Models

ABSTRACT

Arguing that what sets the computer apart from all other teaching devices is its potential for interactivity, this paper examines the concept of interactivity and explores ways in which its power can be harnessed and put to work. A discussion of interactivity in human-to-human communication sets a context within which to view human/computer interaction by looking at the Shannon-Weaver and the Berlo models of communication. Selnow's critical features of interaction are examined, along with Berlo's four levels of communicative interdependence: definitional-physical interdependence; action-reaction interdependence; interdependence of expectations; and interaction. It is noted that Berlo's levels hold many lessons for designers of instructional software. SimCity is then briefly described as a program that allows the student to become a part of its world, where the computer seems to be replaced by an entity whose responses are highly related to the user's responses. A "recipe" for interactivity is proposed which calls for the following ingredients (variables): immediacy of response; non-sequential access to information; adaptability; feedback; options; bi-directional communication; and interruptability. Discussions of the findings of research on the advantages (and drawbacks) of learner control and adaptive instruction conclude the paper. A final statement makes the point that computer instruction systems should emulate, to the greatest extent possible, the richness and flexibility found in human/human interaction while concomitantly exploiting the unique capabilities computers have to offer, thus making the computer and the student partners in the critical art and science of education. (61 references) (BBM)

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Introduction

Since Halcyon Skinner patented what is believed to be the world's first teaching machine back in 1866 (Benjamin, 1988), a progression of technology has enticed visionaries and those simply looking for a better way to teach. A cavalcade of audiotapes, videotapes, television, filmstrips, slides, and computer-aided-instruction terminals has passed through the corridors of education, but have turned out to be disappointing. But the latest addition to our arsenal of educational media is very different. It is so different because it is not a medium such as paper or videotape; it can act, react and interact in ways none of its predecessors could–in ways that are, in fact, quite human-like.

What makes the computer unique is its potential for interactivity. Selnow (1988) sees computers as "interactants in one-to-one communication". Rather than begin with a definition of interactivity, let us begin by thinking about the experience of driving a car. Most people find driving a reasonably positive experience (at least when there is no traffic!). And, indeed, some find it a truly exhilarating experience (the interstate drivers who think they are on the Indianapolis Speedway track). But what makes driving, especially sportscars, fun? The answer, I propose, is interaction -- an extremely high degree of interaction. If it were simply speed and the experience of getting somewhere, a ride on the bus or subway should do the trick. But the fact is that these modes of transportation are not as fun because we cannot interact with them. We cannot communicate with them, nor them with us. Berlo (1960) claims that "Communication represents an attempt to couple two organisms, to bridge the gap between two individuals through the production and reception of messages which have meaning for both." The driver can send messages to the car, and the car can initiate and send messages back to the driver. The messages that are sent by the driver to the car depends on the messages sent by the car to the driver and vice-versa. Feedback determines the next response. That is interaction.

Consider how compelling videogames (and other computer games such as simulations) are. I believe that it is the tight, highly responsive environment of these games which gives them much of their appeal. Compare the experience of playing a videogame with merely watching someone else play one. Watching someone else play is not nearly as exciting as playing the game for oneself. Why? The missing ingredient is interactivity. And which do you think would be more effective, a video of a teacher explaining calculus or a personal tutor explaining it one-on-one? The point being made here is extremely important. It is the potential for interactivity that sets the computer apart from all other instructional devices. Text, color graphics, full-motion video, animation and sound can all be transmitted via media other than the computer. It is interactivity that makes the computer an educational tool like no other — with fantastic educational potential (see Ehrlich, 1990).

A primary purpose of this paper is to examine the concept of interactivity itself. The notion of interactivity is intuitively appealing and much has been written about how computers can be interactive but literature on the topic of interactivity itself is scant. This paper will explore interactivity in some depth. A second purpose is to see how the power of interactivity can be harnessed and put to work. A natural starting point for an inquiry into interactivity is with an examination of the richest and most versatile type of interaction of all: human-to-human communication.

Human-to-Human Communication:

To set a context within which to view human/computer interaction, it is useful to look at some models of human communication, the linchpin of which is interactivity.

The oldest and certainly one of the most popular and useful models of communication was actually born out of a need to describe electronic communication rather than human communication. The Shannon-Weaver model (Shannon and Weaver, 1949; Heinich, Molenda and Russel, 1989) has five essential components: 1) a source, 2) a transmitter, 3) a signal, 4) a receiver, and 5) a destination. If Bill wishes to ask Mary out for a date, Bill (the source) might call her up on the telephone (the transmitter) and ask her if she would go out with him (the signal) whereupon Mary's ears (the receiver) would receive the message which would then be transformed into something Mary's brain (the destination) could understand. It turns out that Mary has had a crush on Bill and so is delighted with the idea of going out with him. Her brain, previously the destination, now becomes the source and the process is approximately reversed.

The Shannon-Weaver model has proved helpful in looking at human/human communication but there are other models perhaps more tailored to the features of human/human communication than the Shannon-Weaver model which originated as a model of electronic communication.

One example is Berlo's (Berlo, 1960) model of communication. This model has six components: 1) the communication source, 2) the encoder, 3) the message, 4) the channel, 5) the decoder, and 6) the communication receiver.

Let us apply Bill and Mary's communication to this model. Bill is the Source. He, the source, has an intention to communicate. This intention is encoded by Bill's vocal apparatus. In more complex communication situations, the source and the encoder may be separate. For instance, the president of a corporation may be the source of some communication, but it is the lower managers which translate the intentions of the president and relay the message to others in the organization. Returning to Bill and Mary, Bill chooses to use his mouth to encode his intention (alternatively, he could have chosen to use his hand and written a letter) and also elects to use the telephone as a channel to transmit his message. Interaction between humans can be very rich.[1]

What Exactly Is Interaction?

Selnow's critical features of interaction:

Before proceeding, we must ask what is interaction, exactly? How will we know when we see it? Selnow (1988) offers a useful place to begin. He proposes the following three features as critical in characterizing interpersonal communication (p. 126):

1. Messages must be receiver specific. The source must tailor his or her communication for each receiver (*this implies, but goes beyond, recognition of the partner*).

[1]Human interaction here means where the parties are present in the same location Written personal communication would fit the definition of interaction except that it is delayed.

2. Message exchanges in the event must follow the pattern of a response contingent progression. Message exchanges are contingent on sequential feedback information (*this acknowledges communicative interdependence and flexibility, but also suggests activity and structure*).

3. The channel must provide for a two-way flow of information to accommodate the essential feedback component.

Berlo's Levels of Communicative Interdependence:

According to Berlo (1960), in communications, the source and the receiver are interdependent. That is, the source affects the receiver and the receiver affects the source. There are four levels of such interdependence:

1. *Definitional-Physical Interdependence*. At this level, the two parties depend on each other for their very existence. Clearly, without a receiver, there is no source, and vice versa. Often two parties are physically there and are talking to each other, but neither is responding to the other; they are each talking about very different things. In this case, they are physically interdependent–they depend on each other's existence in order to encode a communication. All too many instructional programs fall at this level. Software that permits only simple forward and backward movement resides at the definitional-physical interdependence level.

2. *Action-Reaction Interdependence*. The essence of this level of interdependence is the presence of feedback. According to Berlo, "Feedback provides the source with information concerning his success in accomplishing his objective. In doing this, it exerts control over future messages which the source encodes." (pp. 111-112). He uses the example of a speaker who tells a joke to an audience. If the audience laughs, he will probably continue telling jokes, if nobody even cracks a smile then he will either change his jokes or stop telling jokes altogether. Most educational software would probably fall into this category. The computer presents some information and can then branch to appropriate locations in the material depending on the student's actions.

3. *Interdependence of Expectations*: *Empathy*. Empathy, in this sense involves making inferences of what a party is trying to communicate based on what that party does. It involves prediction.

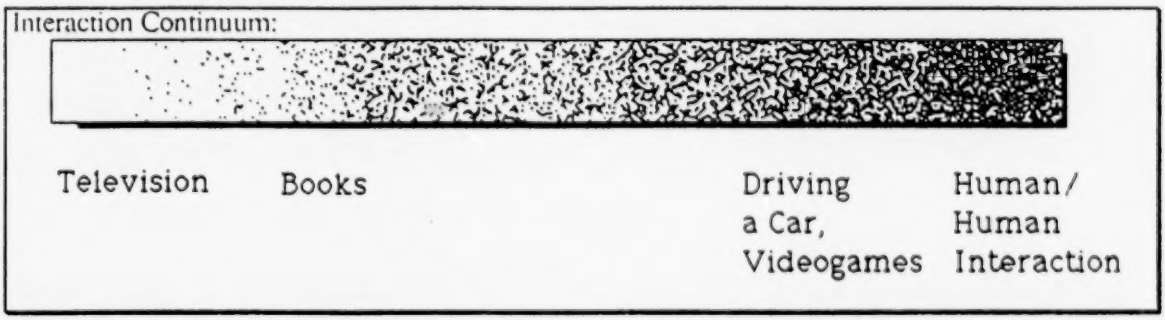
4. *Interaction*. In Berlo's words, "If two individuals make inferences about their own roles and take the role of the other at the same time, and if their communication behavior depends on the reciprocal taking of roles, then they are communicating by interacting with each other." (p. 130). Berlo goes on to say, "When two people interact, they put themselves into each other's shoes, try to perceive the world as the other person perceives it, try to predict how the other will respond." Good computer simulations and games fit in this category.

Berlo's four levels of communicative interdependence hold many lessons to be learned by designers of instructional software. Consider a program that restricts interactivity to flipping through electronic pages sequentially. One may have plenty of opportunities to

press the space bar to advance to the next page, but there is virtually no interactivity going on. One cannot give the computer much feedback. The computer does not exhibit any empathy – it has no way of predicting or adapting to your responses. Neither party can do much more than go back and forth.

Now, consider a program that allows the student to become a part of its world, where the computer seems to disappear and in its place is an entity who's own responses are highly related to the user's responses. An example of such a program is *SimCity*.[2]

It should be obvious by now that interactivity is not an on or off concept. In other words, we cannot say that some entity is either interactive or it is not interactive. Writers have attempted to classify communication into categories such as reactive (learners merely react to computer output), proactive (learners make all the decisions) and interactive (a give and take relationship) (Thompson and Jorgensen, 1989). The implication here is that once something is labelled as falling into one or the other category, it is assumed that it does not have any (or at least, many) attributes in common. The use of this taxonomy makes it difficult to recognize that just about every entity has, to some extent, a definable amount of interactivity. I believe a much more fruitful way (and one that lends itself to empirical studies) of looking at interactivity is to think of it as a property of just about every entity (here we restrict ourselves to common instructional entities such as books, video, etc.), where the amount of that property falls along a continuum from no interactivity to completely interactive. Some examples would be illuminating now.



Do you think books are interactive? They are. When reading a book, the words have some impact on the reader (at least that is what is supposed to happen!). The reader can respond by turning the pages, reading only certain passages, or going back to reread a difficult passage. The book is having an influence on the reader and the reader can issue responses consistent with that influence. What about television? Television can influence the viewer perhaps by changing attitudes towards a product, or by making one happy or one sad, but the viewer has no way of influencing the television in return, short of changing the channel. Perhaps the most interactive of all communications is that between humans in a face-to-face communication. In such situations, the messages are receiver specific, there is a rich feedback mechanism such as content of what is said, tone of voice, body language, etc., and the participants may adjust their messages in response to the others (Weller, 1988). For example, if, in conversing with Mary, Bill notices that his jokes are being met with either a blank stare or a frown, Bill can alter his messages as a result. So, Bill has influenced Mary who has in turn influenced Bill. This feedback loop is

[2]SimCity is an absolutely incredible simulation program published by Broderbund software. It is a supreme example of how to successfully mix education and entertainment. Another excellent example of such a mix is Broderbund's Carmen Sandiego series of educational games.

the hallmark of true interaction. We must remember, however, that people approach communications with others with various needs and goals. Bill and Mary may be talking to one another, but they are not responding to each other. That is, their goal is talking for the sake of talking. We perceive the illusion of interaction because they take turns talking. Critical ingredients such as the use of feedback and tailored messages are missing.

Borsook's Recipe for Interactivity

What makes something interactive? While the term is freely bandied about, interactivity is an ill-defined concept, especially with respect to computers and its importance in instruction. There exists no cohesive definition of interactivity that can be used to guide the creation of computer-based instruction. This absence of guidelines and a dependence on loose, intuitive notions of what interactivity is and what it can do does the enterprise of instructional technology a disservice. The following is a list of variables that are believed to be the key ingredients of interactivity. Just as every instructional system may be said to possess a degree of interactivity that falls along a continuum from none to complete,[3] so each of these variables are present to some degree or another in each instructional system. In educational software one can find anywhere from none or a dash of a particular ingredient to any combination and quantities of ingredients. Interactivity increases to the extent that there is more or less of the following ingredients:

Immediacy of response. Think of the difference between conversing with a friend who is standing right before you and corresponding with her through the mail and you will appreciate the importance of immediacy of response to interactivity. In an educational program, if you wanted to know some more about, say a graph, you could click the mouse button and retrieve a text elaboration or another graph or a video, all immediately. In this sense, computers can allow for greater interactivity than humans! So, interactivity implies a sense of immediacy of response.

Non-sequential access of information. Interactivity allows for accessing and presenting information non-sequentially. Consider two different scenarios. Jack walks into a board room, makes his presentation from start to finish, accepts no questions, packs up, and leaves when finished. Tammy walks into another boardroom and begins her talk but tailors her presentation to the needs of the group. She fields questions, is able to restate some of her points in different ways and is responsive to the needs, concerns and anxieties of her audience. Which meeting would be more effective? Which meeting would you rather attend?

Adaptability. The third primary ingredient of interactivity, adaptability, is actually an implication of the non-sequential component. When two parties interact, there is adaptation taking place. We alter both what we say and how we say it dependent on to whom we are talking. We speak differently to a doctor, friend, professor, a new acquaintance, and a young child. More will be said about adaptability later on.

Feedback. The fourth ingredient of interactivity, feedback, is the information upon which change and adaptations are made. Interactivity stands on the shoulders of feedback. Feedback is what allows interactive systems to personalize and adapt instruction. Personalized feedback is the key to interaction (Selnow, 1988; Jonassen, 1985; Berlo, 1960). "Feedback provides the source with the information concerning his success in accomplishing his objective. In doing this, it exerts control over future

[3] I propose that it is impossible for any system to be at either extreme of the continuum.

messages which the source encodes" (Hooper and Hannafin, 1988; pp. 111-112; see also Schloss, Wisniewski and Cartwright, 1988). Smith (1972) points up the important distinction between feedback and knowledge of results.

1. Knowledge of results does not facilitate performance if learners have incorrect hypotheses about what leads to correct performance. They may not realize they are attending to irrelevancies. They need to know the amount and direction of error as well as the outcome.

2. The information has to be incorporated into the pattern of control and to allow differentiation of relevant and irrelevant cues.

3. The learners always have some knowledge of results from their own sensory feedback, but it may not be sufficient.

So, the feedback package includes more than a response such as "right" or "wrong", it must also include directions for how to correct the situation if it is not right. Therefore, systems that are to be labelled highly interactive must, of necessity, also be said to be systems that utilize feedback extensively. To appreciate the difference feedback can make, think of how difficult it would be to drive a car blindfolded! To use an educational example, compare a computer program that presents material in the same way to every student regardless of how a particular student responds and which offers very few alternatives as to what could be done at any point with a computer program in which feedback to each student is highly responsive to the students' actions. If there is no feedback, there can be no interactivity.

Options. Built into the concepts of adaptability and feedback is the notion of options, our fifth component. Software could not be very adaptive if it did not offer a sufficient number of options to its user. Clearly, if a user can only press the space bar to sequentially page through screen after screen of information, the computer could not extract enough information that could be used to adapt instruction. One of the features that makes one-on-one human conversation so potentially interactive is the wide variety of options available to each conversant. In a conversation between two people that only permitted the use of only six words, there would not be much interactivity. Neither would there be much interactivity between a human and a computer program that offered such a restricted set of "words" with which to converse.

Bi-directional communication. Interactive systems implicate a channel that permits two-way communication. If a computer is doing most or all of the "talking" (i.e. presenting graphic after graphic or text after text), then interactivity is compromised. Just as we would not be satisfied with a telephone connection that only allowed for a one-way conversation, so we should not be satisfied with a computer program that restricts two-way interaction.

Interruptability. Related to *options*, is a party's freedom to initiate a course of action that is removed from previous interactions or to interrupt a currently running sequence. Imagine not being able to change a course of conversation with someone or interrupt a long-winded soliloquy. One would probably not feel a sense of high interactivity in such a case. Related to interruptability is the notion of *grain-size.* Grain-size refers to the length of time required of a given sequence before allowing

further input. If a user cannot interrupt and/or initiate an action, then interactivity is low. A program that requires users to watch a fifteen-minute video before allowing responsive action is clearly not doing its part to introduce interactivity to educational systems.

For completeness, it would now be appropriate to turn to an examination of *learner control*, and *adaptive instruction*, two concepts that have been associated with enhanced interactivity. What we will see is that only adaptive instruction truly takes advantage of the computer's power by accounting for different individual needs and by lending a guiding hand through the labyrinthine paths of knowledge.

Learner Control

When we talk about computer programs that allowing for greater interaction between themselves and the learner, the implication is that those programs hand over some degree of control of the learning experience to the learner. The computer is not the only instructional device that permits the user to control the experience; books, for example, allow a great deal of latitude with which readers can obtain information. What makes the computer unique is its ability to respond to the learner. A responsive device gives learner control unprecedented powers. The question is, is this good?

The advantages of learner control include greater individualization of instruction, increased sense of personal responsibility for learning, and the potential to optimize learning efficiency (Hannafin and Colamaio, 1987). The empirical data, however, suggest that the story is not a simple one. What we will see is that total learner control is beneficial only to those who are already somewhat knowledgeable about a domain or who are generally high academic achievers. It will be argued that by increasing learner control, we are not necessarily increasing interactivity.

A study by Avner, Moore and Smith (1980), divided students into two groups: a computer-control condition where students had to answer questions and could not advance through the lesson if their answers were not correct, and a learner-control condtion where students could advance whenever they chose. There were no significant differences between the computer-control condition and the learner control condition when laboratory procedures involved simple instruction following. There was, however, a significant difference between the groups when the students had to make decisions that required an understanding of underlying principles. Those students who were forced to give a response (computer control), performed significantly *better* than those not forced to do so (learner control). Presumably the students were not knowledgeable about the lab principles before sitting down at the computer. They needed guidance and by providing them with the opportunity to skip over important questions, they had been given "enough rope to hang themselves with." This phenomenon could be called the *too-much-rope syndrome*.

Schloss, Wisniewski and Cartwright (1988) found that freedom to either review or not review material did not significantly affect performance on a posttest. The important factor was whether or not students received cumulative feedback on their performance. Learner control was more effective than program control of review presentation only when feedback was given. According to the researchers, the feedback provides "the learner with important information necessary in making informed choices."

These studies make a point which is becoming increasingly obvious: Learner control is good only for the informed learner. Whether that information comes in the form

of performance feedback or in the form of previously learned knowledge does not appear to be as critical as whether information is available or not. Too much control over the branching of instruction may even lead learners to acquire negative attitudes towards the lesson (Gray, 1977).

The learner control literature seems to confirm the concept that it is the extent to which knowledge is applied to new learning which determines what and how much is learned (Jonassen, 1985b, 1988a, 1988b; Carrier and Jonassen, 1988; Ausubel, 1960). Students who navigate blindly through the myriad paths of instruction materials fall victim to the *too-much-rope syndrome* described earlier. Students who access previously acquired knowledge know what they need to know, know how to get it, and know what to do with it. Students with prior knowledge of a subject can perform equally well under learner as under computer control (Gay, 1986). The corollary is that students who do not bring previously acquired knowledge to a lesson need guidance. Computer-guided branching enhances interaction because without it, the computer either follows a predetermined path (low interaction), branches contingent on the learner's answers (moderate interaction), or turns over full control of branching to the learner (moderate interaction because the computer is not influencing [i.e. communicating] its recommendations) — it is simply reacting to the learner's input. Computer-guided branching maintains the spirit of true interaction which involves receiver specific and influenced messages, and a reciprocal give and take.

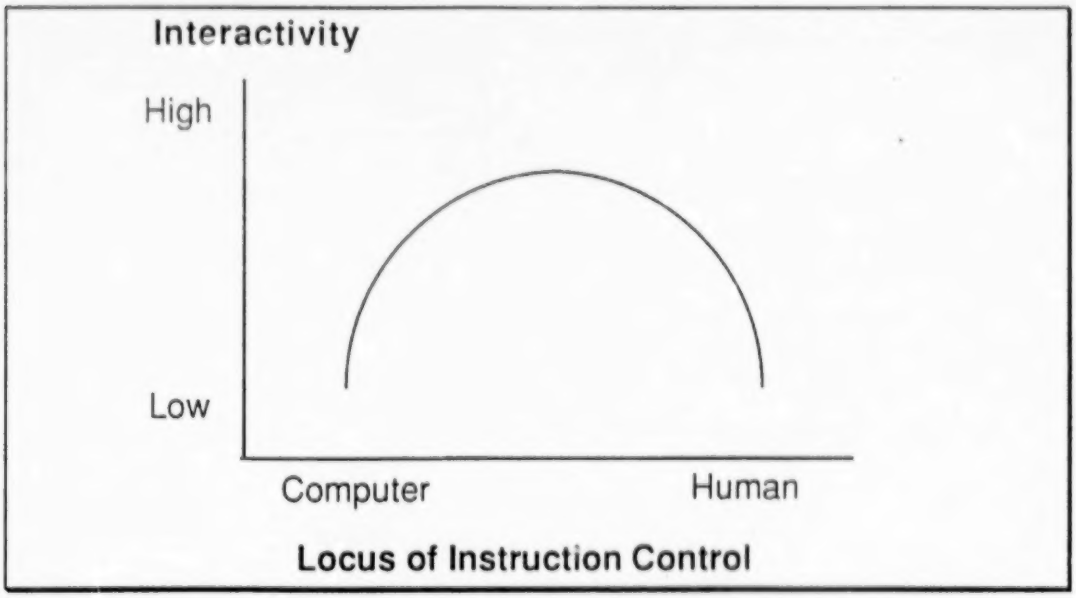
Adaptive Instruction

Now that we have decided that feedback and guided (but not forced) branching is advantageous over giving learners free rein, we are on the doorstep of another different, yet related field called *adaptive instruction*. Adaptive courseware is designed to dynamically alter presentation of instruction as a result of learner idiosyncracies. Elaborate and highly time-consuming models for the creation of adaptive courseware have been proposed (eg. Carrier and Jonassen, 1988), but the idea is simple. Let us consider the lowly, yet eminently useful book. The book cannot change because a student tends to be field-dependent rather than field-independent. It can neither assess the student's knowledge nor the student's personality. What is printed is printed. It cannot change. Now let us consider a good human instructor. She can note that the student knows about and likes baseball and can attempt to frame examples in baseball terms[4]. She can note that reading comprehension seems to be a problem and so she can provide remedial support in this area. The student provides feedback to her enabling her to fine-tune her responses and her responses, in turn, influence subsequent feedback. This feedback loop is one of the hallmarks of interaction. To the extent that we consider adaptation to enhance interaction, and to the extent that we consider enhanced interaction beneficial to the student, then we could confidently assert that adaptation is indeed beneficial to the student.

Contrary to claims and implications in the literature, increasing learner control is not commensurate with increasing the quality or quantity of interactivity offered by an instruction system. Research has shown that allowing all but the most bright and knowledgeable free rein at controlling sequencing, pacing, amount of practice and level of difficulty (Higginbotham-Wheat, 1990) results in disappointing performance. Even affective measures showed no advantage for such systems (Lahey, 1978). Why is this so?

[4]Of course, some subjects, such as Math and Statistics are more amenable to a baseball analogy than other subjects such as English or History, but the point is that the teacher can make that assessment.

Although the area of learner control is complex and there exists different kinds of learner control (Higginbotham-Wheat, 1990), the idea is quite simple: By giving learners greater control over various aspects of instruction such as pacing, and sequencing, they can tailor the instruction to their own style of learning, thereby enhancing the efficacy and efficiency of learning. Furthermore, this greater freedom should motivate students which should enhance learning even more. Unfortunately, all but the most bright, knowledgeable and/or motivated students simply get lost or frustrated — the too-much-rope syndrome. I argue that the reason for the disappointing results is that learner control simply shifts the locus of control from the computer (where the computer controls all aspects of the learning experience) to the learner. As locus of control shifts from one party to another, interactivity is diminished. Indeed, the very term *locus* of control implies an imbalance that is antithhesis to true interactivity.



Adaptive or guided instruction simulates a good, caring teacher who knows the material, and who takes the time and makes the effort to learn about and capitalize on each individual student's strengths, weaknesses and overall idiosyncracies. The student is encouraged, but not forced, to follow the teacher's suggested path. The student responds to the teacher and the teacher responds back to the student. Each response is contingent on the other's response, with personalized feedback the guiding light. This is interactivity. It has all the requisite ingredients of interactivity.

In addressing the issue of how motivation and curiosity can be stimulated so that students will go beyond inefficient browsing to goal-oriented and motivating learning, Kinzie and Berdel (1990) state that simply handing over all instructional control to the student is not necessarily good. Most students need to be guided. The argument for learner control is predicated on the idea that each student knows best what he or she needs to learn. The problem is that most students lack self-regulation skills. The trick is to somehow maintain the benefits of learner control yet somehow circumvent its limitations. These authors propose that in a hypermedia system, "learners can be prompted during practice to look up words, ask for alternative presentations (diagrams, spoken words, etc.), take notes or make drawings, or move about, depending on system capabilities." Some of the examples they give follows:

Hint	When to Provide It
"That word, 'mandible,' is a new one. If you don't know it yet, check the dictionary for a definition."	When a dictionary entry is available
"From here, you can find out about the bees' *waggle dance* or about the long distances bees will fly to find food."	When there are multiple links available to related information.
"You might want to diagram the social structure of a bee colony, to help you remember. Use the drawing tablet."	After user has been exposed to the basic information needed for such a diagram.

Using such a technique we have the best of both worlds. To the student it is like having a caring, patient teacher sitting right there. Learner control is still available. The sequence of exposure is not fixed as it is with a videotape — the student is free to explore. Yet the computer always has a hand extended when the footing gets a little unstable or when the material being presented requires some extra support. Advancements in artificial intelligence cognitive science will help to personalize the guidance to the needs of the individual.

In this sense, the computer can be even better than a personal human tutor. Even the most willing and able of human tutors could not instantly call up a color picture of a particular patient's heart, present an audio recording of its beating sounds, provide background information on the patient and on the patient's disease, summon definitions of difficult terms, and show an animated sequence highlighting the flow of blood through the organ, all the while monitoring the student's progress, making suggestions and remaining endlessly patient!

The point being made here is important enough to restate explicitly: *We should aim to emulate in computer instruction systems, to the greatest extent possible, the richness and flexibility found in human/human interaction while concomitantly exploiting the unique capabilities computers have to offer. That means making computer and student partners in the critical art and science of education.*

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